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STUDIES FOR STUDENTS.

THE DRIFT—ITS CHARACTERISTICS AND RELATIONSHIPS.

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Definition of the drift. The northern part of the United States, as well as a large part of the Dominion of Canada, is covered by a mantle of incoherent materials composed of clay, sand, gravel and bowlders. These various materials are sometimes intimately commingled, and sometimes more or less distinctly separated from one another. The separation may be either lateral or vertical. One region may be covered by well-assorted gravel or sand, while a contiguous area may be covered by bowlder-bearing clay, or by an unassorted mixture of bowlders, gravel, sand and clay; or layers of sand and gravel may alternate with layers of unassorted bowlder-bearing material in the same vertical section. Where bowlders, gravel, sand and clay are associated without trace of separation or arrangement, any one of them may predominate over the others to any extent, or all may be commingled in approximately equal proportions.

Through this mantle of unconsolidated material the underlying rock often projects. Many natural and artificial sections likewise reveal the rock beneath. From these sections, and from the general relations of the drift to the underlying rock, it is seen that the surface materials are not restricted to any particular sort of rock. They occur on limestone, sandstone, shale, gneiss, granite, or any other sort of rock, with apparent indifference.

Another feature which at once attracts attention is the fact that the body of material overlying any particular kind of rock contains many fragments or bowlders of rock which could not have been derived from it. Where the underlying rock is limestone, bowlders of gneiss, granite, sandstone, or diabase are often found in abundance in the overlying mantle of loose materials. Such bowlders cannot be supposed to have come from the disruption of the limestone, for limestone does not contain the materials of which they are composed. In like manner, the covering of unconsolidated material which overspreads the surface of gneiss within the area specified, often contains bowlders from a great variety of other formations, such as limestone, sandstone, and shale. Disintegration or disruption of the gneiss could by no possibility have given rise to limestone or sandstone or shale, since gneiss contains nothing from which these rocks could come by any simple process of disintegration or disruption. Not only does the composition of the loose materials overlying the solid rock in the northeastern part of the United States forbid the idea of their origin by the decay of the underlying rock, but in addition to this, the physical condition of the bowlders has a like significance, since many of them show no signs whatever of disintegration. They often look as fresh as if quarried but yesterday from their parent formations.

This aggregate of surface material which overlies different formations indiscriminately, and which is composed of materials which could not have been derived wholly from the underlying rock, is called *drift*. It was long since recognized that the materials of which it is composed did not originate where they now lie, and that, in consequence, they sustain no definite genetic relationship to the formations of the territory over which they are spread. Long before the drift received special attention at the hands of geologists, it was believed that it had been transported from other localities to those where it now occurs. The early conception was that it had been brought or "drifted" to its present position from some outside source by means of water. It is to this conception of its origin that the formation owes the name *drift*. In the early days of geology this surface material, which often effectually conceals the rock beneath, was regarded as uninteresting in itself, and an obstacle to the study of the underlying formations, which were regarded as the proper field of geological inquiry. So long as the drift was looked upon in this way, it received but little attention; but within recent years it has been the object of critical investigation, and there are now few departments of geology which are attracting a larger share of professional attention, and few departments which have yielded, or are yielding, more interesting and more important results. The accessibility of the drift, and its importance in shaping the details of the surface throughout so wide an area, have made it a favorite subject of study for a large number of students.

THICKNESS OF THE DRIFT.

In general. The thickness of the drift varies greatly. Over large areas its depth is so slight and so unequal that the underlying rock is frequently exposed. This is much more generally true in mountainous and hilly regions than in plane ones, though regions are not wanting where frequent rock exposures are associated with a topography of but slight relief. The mountains of New England, the Adirondacks, the Catskills, the Highlands of Northern New Jersey, and the adjacent parts of New York and Pennsylvania, may serve as examples of mountainous regions where the underlying rock is but poorly concealed by the mantle of drift. Areas of plane or gently undulating topography where the drift is so thin as to allow the underlying rock to be exposed frequently are by no means rare in the drift-covered area, but within the area of the United States, they are not generally of great extent.

Over wide areas the drift is so thick that the underlying rock is rarely seen except where natural or artificial excavations of great depth have been made. In such cases, excavations afford the only means of knowing the thickness of the drift. In still other regions the covering of drift is so massive that even the deeper valleys and the wells fail to penetrate it to its base. Over considerable areas in Northwestern Minnesota, for example, the older formations are so deeply buried by the drift that they have not been reached by the deepest excavations and borings that have there been made, though this does not mean that they are beyond the reach of deep borings. The drift is also very deep in many parts of Iowa, Illinois, Indiana, Ohio, Michigan, and New York. Depths of something more than five hundred feet have been recorded in a few places. Such thicknesses are rare; but thicknesses of two hundred or three hundred feet are by no means uncommon. The average thickness throughout the drift-covered area is much less, but no very accurate estimate can be made on the basis of present knowledge. The average thickness for the Upper Mississippi basin has been estimated to be not less than 100 feet.[1] For the eastern part of the United States, this figure is probably much too high.

The variations in thickness may be great within short distances. One hill may have barely drift enough to cover the rock, while the next may be composed of drift from base to summit. The drift may be thin on the hills, and deep in adjacent valleys, or, less commonly, the reverse may be the case. Thicknesses varying from nothing to one hundred or two hundred feet are not rare within a single square mile, and sometimes occur within much narrower limits. The natural sections exposed along the sides of valleys, and along the cliffs of seas or lakes, sometimes illustrate the abruptness of the variations in thickness. At one point along the course of a river valley the total face of the bounding bluffs, scores and perhaps hundreds of feet in height, may be of drift, while at adjacent points close at hand the entire faces of the bluffs may be composed of rock alone, or of rock no more than drift-coated. It follows that the surface of the subjacent rock is sometimes very uneven, and that its irregularities do not always stand in definite relation to the present topography. Where extensive excavations are favorably situated, it may sometimes be shown that the roughnesses of the rock surface beneath the drift are due to the existence of deep valleys excavated in the rock surface before the drift was deposited, and that these valleys do not now appear at the surface because they have been filled by the drift, and thus obliterated as surface features. Since the deposition of the drift, the rain and the rivers have in many places carved out new valleys in its surface. Sometimes these valleys, developed since the deposition of the drift, have sunk themselves through it, and into the rock below.

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[1] CHAMBERLIN: Geikie's "The Great Ice Age," 3d edition, 1894.

While abrupt variations in thickness characterize the drift of certain regions, and especially regions of considerable relief, they are not universal. Over large areas its thickness is nearly uniform. This is more likely to be true in plane areas than in areas of marked relief. If the thickness of the drift be approximately uniform in flat regions, it follows that the surface of the underlying rock must be approximately level. Where the depth of the drift is uniform, or nearly so, it may be scores or even hundreds of feet, or it may be very slight, affording no more than a thin soil and subsoil. It is even true, now and then, that areas a few or many miles in extent are nearly free from drift within the very heart of larger tracts, which, with these exceptions, are deeply covered. While the thickness or thinness of the drift is measurably independent of both altitude and topography, it is rather more commonly thick in low and nearly level regions than on high and rough areas. Apart from all considerations of altitude and topography, the distribution of thick bodies of drift is not altogether fortuitous. Regarding the drift sheet as a unit, its greatest average thickness is neither at its extreme edge nor at its centre, but somewhere between the two positions and distinctly nearer the former than the latter. This is not to be construed to mean that the drift is not often thick both without and within the zone here specified, or that it is never thin in this zone.

Any theory of the drift must take account of these facts. The agent or agents to whose activity it is to be attributed must have been able to leave many small patches, not always higher or lower than their surroundings, essentially without drift. They must have been such as could have left the drift now in thick beds, and now in thin, over limited or extensive areas, without close dependence on topography or altitude, yet without complete independence of either.

Thickness of the drift along its borders. At its margin, the drift sometimes thickens so as to constitute a considerable ridge. This is the exceptional condition of things rather than the general. In other cases the drift grows thinner and thinner toward its edge, its limit being still well defined, and constituting a definitely traceable line. In still other cases the drift feathers out at its edge, ceasing to exert any observable influence on topography. In such cases the border may become so ill defined that it is traceable only with difficulty.

DRIFTLESS AREAS.

Besides the many small patches of bare or nearly bare rock over which the drift forces acted without leaving deposits of much thickness, there is, far within the outermost limit of the drift-covered country, an area several thousand square miles in extent, where drift is altogether absent. This area lies mainly in southwestern Wisconsin, but embraces small adjacent areas in Illinois, Iowa, and Minnesota. The absence of even a meager coating of drift from this area has led to the conclusion that the agency or agencies which produced the drift were not here operative. There is probably a second, smaller driftless area, also, in the axis of the Mississippi basin, occupying a part of the elevated land between the Illinois and Mississippi rivers, near their junction. This area is much nearer the border of the drift, and appears much less anomalous than the other. Neither of the driftless areas are notably higher or lower than their surroundings, though both are notably rougher.

In considering the origin of the drift, we are forced to exclude as the sole or principal agents such as would not allow the existence of driftless areas, neither notably higher nor lower than their surroundings, within the very heart of the great sheet of drift.

CONSTITUTION OF THE DRIFT.

Physical heterogeneity. It is certainly a striking fact which confronts us when we see huge bowlders, sometimes many tons in weight, imbedded in earthy material as fine as that which our most sluggish streams are carrying in suspension. Between these extremes of coarseness and fineness, there are materials of all grades. The proportions of coarse and fine materials are not at all constant. The fine may predominate at one point, the coarse at another. From predominance of fine to predominance of coarse the changes may be abrupt, and frequently repeated. Any one of the constituents of the drift—bowlders, gravel, sand or clay—may predominate over any or all the others to almost any extent. It follows that any one of these may nearly or quite exclude the others, though the drift is rarely composed of large stones only. While, therefore, the drift is remarkable for its physical heterogeneity, and while this heterogeneity is a general characteristic, still there are localities where it is not extreme. There are localities, indeed, where the drift is remarkably homogeneous. In such cases its constituents are more commonly fine than coarse, and rather more commonly of sand than of clay, although drift made up principally of the fine, earthy material which is popularly called "clay," is by no means rare.

From the physical heterogeneity of the drift, it is clear that the agent or agents to which it owes its origin, or to which at any rate much of it owes its origin, must have been able, under some conditions, to carry and deposit at one place and at one time, materials as fine as the finest particles of silt or mud, and bowlders many tons in weight, while they were competent, under other circumstances, to make deposits of much less extreme diversity.

Lithological heterogeneity. The drift of any given area generally contains pieces of some such assemblage of rocks as the following: shale, sandstone, limestone, quartzite, gneiss, schist, porphyry, diabase, and gabbro. Not all these types of rock are represented in the drift of every locality, and some localities contain rock fragments of other types. But if all the foregoing kinds of rock are represented in the drift of a given locality, the drift containing them cannot be looked upon as possessing unusual lithological heterogeneity. Any type of rock represented in the drift may be represented by masses as large as the largest bowlders which the drift contains, and, at the same time, by the smallest particles which will allow of identification. In other words, the physical heterogeneity of any given sort of rock represented in the drift may be about as great as the physical heterogeneity of all.

The various types of rock represented in the drift of any locality are not generally in equal proportions. It is often true that some one type predominates, and this predominance is often striking. But in spite of this, the lithological heterogeneity of the drift is a well-nigh universal characteristic. Any hypothesis which essays to explain its origin must take account of this fact.

We must suppose that the granite of the drift came from some place or places where granite is the native surface rock, since we know of no other possible source for it. We suppose that the shale, sandstone, and limestone of the drift came from regions where shale, sandstone, and limestone severally occur, as the uppermost formations beneath the drift. But so many sorts of rock as frequently occur in the form of loose bowlders in the drift of a given place, do not often occur as surface formations in closely contiguous localities. Within the area covered by the drift there are rarely more than a limited number of rock formations appearing at the surface in closely associated areas. From its lithological heterogeneity, therefore, we must conclude that the sources of the drift were various and wide-spread; and if we conclude that its sources were wide-spread, we have no alternative but to conclude that the agencies which were concerned in its production were capable of wide-spread action.

Not only do we conclude from the lithological heterogeneity of the drift that it came from wide-spread sources, but we may reach positive conclusions concerning the minimum areal limits of these sources. By a careful study of the lithological character of the stones of the drift at any given point, and by comparing them with the formations of solid rock in all directions from this point, it is generally possible to determine the exact formation from which many of them came. If the surface exposures of the formations from which the identifiable bowlders came be very small, we are able to draw definite and positive conclusions concerning both the direction of transport of the bowlders in question, and the distance which they have journeyed. If the surface exposures of the formation whence they came be large instead of small, the conclusion which could be drawn would be confined within less narrow limits.

If the determination of the direction and distance of transport rested on the identification of a single type of rock, it would be necessary, in order to make the conclusion absolute, to prove that there is no second source, seen or unseen, whence the given type of bowlders could have come. Manifestly this might be a very difficult thing to do. But if identity can be established between various and diverse types of rock found in loose pieces in the drift of a given locality, and an equal number of formations in beds or *in situ* elsewhere, the case becomes much stronger, for it is almost beyond belief that two complex but lithologically identical series of rock formations, embracing bowlders of so many types as frequently occur in the drift, exist in different directions from any given area. It follows that where identity can be established between a wide-ranging series of bowlders and rock fragments in the drift, and an equally complex succession of diverse formations *in situ* lying in a common direction from the drift which contains the identified types of rock, the conclusion that the former came from the latter is so highly probable as to amount to moral certainty. The known facts concerning the distribution of geological formations make it incredible that a complex succession of identical formations may lie similarly in a second direction from the given locality of drift, and yet be wholly concealed.

It is not to be understood that it is possible to trace every bowlder of the drift to its exact source. Far from it. It is often impossible to tell from what formation a bowlder came. An unfossiliferous Cambrian sandstone may be indistinguishable from an unfossiliferous sandstone from various other formations. Even if it be possible to determine the formation from which a given bowlder came, it does not follow that its exact or even its approximate geographic source can be determined. It may be possible, for example, to say that a given bowlder of the drift came from the Laurentian formation. But the Laurentian formation is exposed over so great an area that it might not be possible to tell, even approximately, the direction whence the bowlder in question came, or the distance it has journeyed. In spite of these limitations, there are some types of rock, and some associations of types of rock, which are available for the determinations here suggested. Drift bowlders derived from any formation possessing distinctive characteristics, and exposed in a small area only, give very definite information concerning both the direction and the distance of their movement. Where complex associations of bowlders occur, their joint testimony may be tolerably definite on these points, even when that of each type, taken singly, fails to be so.

The fine material of the drift. The fine, earthy material of the drift is popularly called clay. If it be critically examined, it teaches significant lessons. It is found to differ in some essential respects from the mineral matter which makes up the soil and subsoil of driftless territory. The latter is composed principally of the insoluble ingredients of decomposed rock, while the former is often nothing more nor less than pulverized rock, the soluble constituents as well as the insoluble being present. If it be examined under the microscope, tiny particles of all the principal minerals which enter into the composition of any of the bowlders of the drift of the same locality may be recognized In the clayey part of the drift, the dolomite and calcite of the limestone, the sand grains of the sandstone, the quartz, orthoclase, plagioclase, mica, hornblende, augite, olivine, magnetite, etc., and even the rarer apatite, tourmaline, zircon, garnet, etc., of the crystalline rocks, may generally be found in microscopic particles, if bowlders containing these minerals are at all plentiful. In general, the minerals which are abundantly represented in the drift bowlders of any locality, are relatively abundant in the fine earth of the drift of the same locality, while the rarer minerals of the bowlders are correspondingly rare in the accompanying clay. To this general statement there are some exceptions. The mineral particles of which the fine parts of the drift are composed often appear as fresh as if but just broken from the crystals of undecomposed rock. Where the particles are large enough so that their forms and surfaces can be distinctly made out, they are seen to be predominantly angular in shape, and to be bounded by fracture faces. They are just such particles as might result from grinding up together various sorts of rock. Furthermore, the fine earthy matter of the drift of any locality is of such mineralogical composition as to suggest that it was largely made from the grinding up of just those sorts of rock which are now represented in the large and small stones of the drift. The physical nature of the earthy matter of the drift, taken together with its mineralogical and chemical constitution, leaves no room for doubt that it is nothing more nor less than "rock flour," the product of mechanical grinding. The agencies which produced the drift must have been able to pulverize rock. No theory which does not take this into account can be acceptable.

STRUCTURE OF THE DRIFT.

Stratification. Much of the drift is distinctly stratified, and much of it is altogether devoid of stratification. Its structure is altogether independent of lithological heterogeneity, but is intimately connected with physical heterogeneity. Extreme physical heterogeneity implies absence of stratification, but absence of extreme physical heterogeneity does not imply stratification. In many cases drift composed almost wholly of earthy material, so fine as to be popularly called clay, is wholly without stratification. In such cases there are generally some stones associated, even though they be small. Heterogeneity exists, but is not extreme. In some places, though rarely, drift composed almost wholly of sand, and therefore not remarkably heterogeneous physically, is still without stratification.

While the unstratified drift may be nearly homogeneous physically, the stratified drift never reaches extremes of heterogeneity. It may be either coarse or fine, but the very coarse and the very fine do not coexist. While there are occasional beds of bowlders the relations of which suggest stratification, the usual limit to the coarseness of stratified drift is coarse gravel. Now and then large bowlders occur in the stratified gravel, sand, or silt, but these bowlders cannot be regarded as partaking of the stratified character which affects the matrix which encloses them. They interrupt the stratification, as may often be distinctly seen. They are accidents in the stratified deposits. No part of the drift, as that term is generally understood, appears to be so fine and so homogeneous as to fail of stratification because of its fineness and homogeneity. The single apparently well-marked exception to this statement (some parts of the loess) need not be here considered.

It is sometimes the case, as fresh cuttings through the drift show, that lenses or pockets of stratified gravel or sand occur in the midst of thick beds of unstratified drift. The reverse is also sometimes true, considerable masses or chunks of unstratified drift being now and then found in the midst of extensive stratified deposits. This association, however, is much less common than the other. Where the stratified drift occurs in extensive beds, it may overlie or underlie the unstratified, or the two may alternate with each other repeatedly in vertical succession in a single section.

In some regions, the unstratified materials predominate greatly over the stratified. In other regions the reverse is true. On the whole, stratified material is more abundant in valleys, and on low areas adjacent to high ones, than elsewhere, but there is no hard and fast topographic relation between the two types. The associations of the two phases of drift are often such as to leave no room to doubt the essential contemporaneity of their origin. The lithological likeness of their materials leaves no room to doubt that the two phases of the drift came from the same general source. From these considerations we conclude that the drift agent or agents must have been capable of producing deposits which were sometimes stratified and sometimes unstratified, and that in many places the deposition must have occurred under such circumstances as to allow of the frequent change from the one phase of deposition to the other.

Foliation of the unstratified drift. While the finer part of the bowlder-clay — the matrix in which the bowlders are set — shows no stratification, it frequently has a sort of structure which may be termed foliation. Roughly speaking, it is comparable to the foliation of gneiss, though of course without the crystallinity of the latter, and without differentiation of its mineral constituents. The foliation is always somewhat irregular, but is usually approximately horizontal, or approximately parallel with the surface. The regularity of its development is usually interrupted where it comes in contact with a bowlder. The foliation lines have a tendency to curve up over, and down beneath, the same, while at the centre of the sides of the bowlder they are rarely developed. The study of this foliation structure suggests that much of it is the result of pressure. In this case, the approximate horizontal direction of the parting planes suggests that the pressure was not far from vertical. In some cases the foliation is such as to suggest that it is the result of a shearing movement in the fine, earthy material. The position of the horizontal cleavage planes suggests that the pressure inducing the shear must have had a horizontal element.

Foliation is restricted to the unstratified portion of the drift, though even here it is by no means universal. It is rarely so distinct as to be obtrusive, and may easily escape the observation of those whose attention has not been called to it. The true theory of the drift must be one which will allow much of the unstratified drift to have been subject to great vertical pressure, and perhaps to shearing, at the time of its formation, or since.

SHAPES AND MARKINGS OF THE STONES IN THE DRIFT.

If the stones in the drift be carefully examined, they are found to possess significant features. If a goodly number of them be collected from the unstratified drift, it will be seen that, while their surfaces are often smooth, their forms are, on the whole, somewhat unlike those of stones rounded by rivers or by waves. While some of them are round or roundish, many others are many-sided. Their faces are often beveled. They have been worn, but the wear appears to have been effected by planing rather than by rolling. The planed sides may meet each other at any angle, though the angle along the line of junction of two faces is rarely sharp. With these planed and sub-angular bowlders and stones there are associated few or many well-rounded ones showing none of the characteristics just noted. With them also, there are occasional angular masses of rock bounded by fracture faces, which do not appear to have suffered notable wear.

If an equally large number of stones from the stratified drift be selected for examination, it will be found that rounded, water-worn forms predominate. On the other hand, specimens of the many-sided, plane-faced forms, though much less common than in the unstratified drift, are not always altogether wanting. This distinction affects large and small stones alike. It characterizes bowlders a foot in diameter, if so large stones occur in the stratified drift, and it characterizes fragments less than an inch in diameter. In case large bowlders occur in the stratified drift, they are rather more likely to have the sub-angular form than the smaller ones.

Another peculiarity goes along with the foregoing. The planed, sub-angular bowlders and rock fragments which characterize especially the unstratified drift, are often distinctly marked with one or more series of lines or scratches on one or more of their faces. The lines of each series are parallel with one another, but the lines of separate series may cross each other at any angle. Multiple series on a single face are not rare, though less common than single series. Multiple series on multiple faces are rather infrequent, yet every student of the drift has seen them many times. Similar markings are not unknown on the well-rounded stones of the drift, though they are here much less abundant than are those of sub-angular forms.

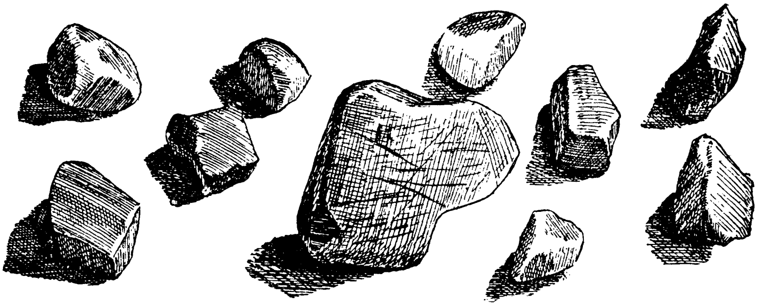

Fig. 1. Characteristic forms of small stones taken from unstratified drift. The contrast in form between these and water-worn pebbles is evident at a glance.

These markings, or *striæ*, as they are called, do not affect all the stones, or even all the sub-angular stones of the drift. If fifty per cent. of those occurring in the unstratified drift of any locality are striated, this is to be looked upon as a large proportion. On the other hand, even the unstratified drift locally contains so few striated stones that a single one is hard to find, even when good exposures are at hand. So far as concerns abundance of striæ, something depends on the relative proportions of coarse and fine materials. Much also depends on the differences in hardness between the various constituents. The striæ are much more abundant on the softer stones, such as limestone, than on the harder, such as quartzite. In much of the stratified drift, striated stones are rarely found. But in certain phases of it, they are no rarity. Where they are abundant, their forms are likely to be sub-angular, just as in the unstratified drift. Striation of surface, and sub-angularity of form, seem to go together.

The true theory of the drift must involve the action of an agent or of agents which, under normal conditions were capable of planing and beveling and striating many stones, especially the softer ones of the unstratified drift, while rounding and leaving unstriated most of those of the stratified. But the agents must have been such that under certain circumstances their activities failed, on the one hand, to leave more than a very small percentage of the stones of the unstratified drift beveled and striated, while, on the other hand, they sometimes permitted the stratification of gravels containing many sub-angular, plane-faced, striated stones, varying in size from pebbles to bowlders.

The Sources of the Drift.

Direction and distance of transportation. By tracing identifiable constituents of the drift back to their sources, it has been found that the general direction of drift transportation in the United States was from north to south. From this general direction there are many and considerable local deviations, both to the the east and west. Generally speaking, it has been found that the larger part of the drift of any locality has not been transported any great distance, though a small part of it has usually traveled far. Even at the southern margin of the drift, bowlders are sometimes found which have come from territory north of our national boundary. Those materials which have come farthest are generally of hard rock. These general statements are not without local and striking exceptions.

The forces which are responsible for the drift, therefore, must have moved, in general, from north to south, and must have been capable of local and considerable deviation both to the east and west. They must have been active over an extensive area. They must have been forces capable of gathering and carrying materials in such wise that, at the time of their deposition, the larger part had been transported but a few miles, and in such wise that the contributions of various formations to the drift of any locality are, in a rough sort of way, inversely proportional to their distance. The drift forces must have been able also to carry large blocks of rock, and preferably hard rock, great distances, at the same time that they frequently carried a large proportion of the fine materials deposited at any given point, trivial distances only.

Size of bowlders in relation to distance from their source. Bowlders of a given type can sometimes be referred to a single source of very limited area. In such cases, it has been repeatedly noticed that the average size of the bowlders becomes less with increasing distance from their source, though individual exceptions to this rule are sometimes striking. This might be accounted for, conceivably, on either of two suppositions. Either the drift forces were not able to move the large bowlders so far as the smaller ones, or their size was reduced in the process of movement. If the latter conjecture be the correct one, the smaller bowlders, which are farther from their source, should show evidence of greater wear than the larger ones, which have not been carried so far. This might also be the case if the first supposition be the true one. For even if the drift agents could carry only the smaller bowlders considerable distances, these smaller bowlders might be worn more in their longer journey, than the larger ones, in their shorter. Between the two hypotheses the greater wear of the smaller bowlders might not therefore be decisive. But the extreme physical heterogeneity of the drift clearly indicates that the drift agents were, on the whole, very independent of the size of the materials handled. Bowlders many tons in weight were sometimes carried scores of miles. In view of this, the conclusion that the decrease in size of bowlers with increasing distance from their source is the result of wear suffered during the transit, seems the more probable. If this conclusion be correct, the drift force or forces must have been able to wear effectively the materials carried, during the process of their movement.

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[To be continued.]